

REMARKS

Claims 2-5, 8 and 10-12 are pending in this application. Claim 8 has been amended. Claim 6 has been canceled. Claims 41-44 have been newly added.

Claims 2-5, 8 and 10-12 stand rejected under 35 U.S.C. §103 as being unpatentable over Patel et al. (US Patent No. 5,374,578) ("Patel") in view of pages 157-160 of Van Zant, *Microchip Fabrication, A Practical Guide to Semiconductor Processing*, 3d Ed. McGraw-Hill (New York 1997) ("Zant") and either of Emesh et al. (U.S. Patent No. 5,728,603) ("Emesh") or Chivukula et al. (U.S. Patent No. 6,066,581) ("Chivukula"). The rejection is respectfully traversed.

The claimed invention relates to a method of fabricating a semiconductor device according to which an oxygen-deficient dielectric film is subjected to wet oxidation in a rapid thermal process chamber. As such, independent amended claim 8 recites a method of fabricating a semiconductor device by "depositing an oxygen-deficient dielectric film having a dielectric constant of at least about 25 over an underlying layer" and "subjecting the dielectric film to a wet oxidation with steam provided by heating a mixture of hydrogen and oxygen gases in a rapid thermal process chamber at a temperature of at least about 450 °C and for a duration which increases the oxygen content of the dielectric film, wherein the ratio of hydrogen to oxygen gases in the mixture is in the range of about 0.1 to about 0.8." Independent amended claim 8 further recites "subjecting the dielectric film to a heat treatment in an ambient comprising a stabilizing gas selected from the group consisting of N₂, O₂, O₃, NO, and N₂O."

Patel relates to a "method for forming a ferroelectric capacitor using ozone anneals." (Col. 2, lines 7-9). According to Patel, anneal processes are performed in "an ozone atmosphere using a rapid thermal anneal process (RTA) or a furnace anneal." (Col. 3, lines 63-66). This is because "ozone is preferred (to oxygen) in that it significantly decreases the number of lead (Pb) atoms lost during annealing as compared to using a conventional oxygen anneal in a furnace." (Col. 4, lines 18-22).

Zant describes dry oxidation systems as “oxidant sources” for microchip fabrication. According to Zant, “[I]n the dry oxidation system, gaseous oxygen and hydrogen are introduced directly into the oxidation tube . . . and, under the influence of the high temperature, form steam.” (Zant at 160).

Emesh relates to a method of forming a crystalline perovskite phase of a ferroelectric dielectric material for an integrated circuit. (Abstract). According to Emesh, “a layer of amorphous ferroelectric precursor material” is deposited on a substrate and then annealed at “a temperature sufficient to cause a phase transformation to a ferroelectric crystalline perovskite phase” in an oxidizing ambient in presence of water vapors. (Col. 3, lines 21-30). The annealing step is carried out at “a temperature below 500 °C.” (Col. 3, lines 41-45). This way, “many of the problems . . . related to the relatively high temperature which is required for processing deposited ferroelectric layers to form a crystalline phase of the ferroelectric dielectric material” are avoided. (Col. 3, lines 7-14).

Chivukula relates to a “sol-gel precursor mixture forming a perovskite ferroelectric material and a method for forming a ferroelectric material.” (Abstract). Chivukula teaches that water vapors are introduced into “an annealing atmosphere comprising oxygen” for the formation of the ferroelectric material. (Col. 13, lines 36-40). Chivukula also teaches that “[O]zone is preferably added to the annealing atmosphere to speed up oxidation.” (Col. 13, lines 46-47).

The subject matter of claims 8, 2-5 and 10-12 would not have been obvious over Patel in view of Zant and either Emesh or Chivukula. First, not all claim limitations are taught or suggested by the prior art, either alone or in combination. None of Patel, Zant, Emesh or Chivukula teach or suggest the step of “*subjecting the dielectric film to a heat treatment in an ambient comprising a stabilizing gas selected from the group consisting of N₂, O₂, O₃, NO, and N₂O*” after the “wet oxidation with steam provided by heating a mixture of hydrogen and oxygen gases in a rapid thermal process chamber . . . wherein *the ratio of hydrogen to oxygen gases in the mixture is in the range of about 0.1 to about 0.8,*” as independent amended claim 8 recites (emphasis added).

Zant is silent about “a wet oxidation with a mixture of hydrogen and oxygen gases in a rapid thermal process chamber at a temperature of at least about 450 °C and for a duration which increases the oxygen content of the dielectric film,” as independent amended claim 8 recites (emphasis added). Patel is also silent about a wet oxidation process, much less about “a *wet oxidation* with steam provided from a mixture of *hydrogen and oxygen* gases in a rapid thermal process chamber at a temperature of at least about 450 °C and for a duration which increases the oxygen content of the dielectric film, wherein *the ratio of hydrogen to oxygen gases in the mixture is in the range of about 0.1 to about 0.8,*” as independent amended claim 8 recites (emphasis added).

Similarly, Emesh fails to teach wet oxidation with steam provided from a mixture of hydrogen and oxygen. Emesh teaches rapid thermal annealing where “[W]ater vapour was conveniently introduced into the annealing atmosphere . . . by passing oxygen (O₂) through a double bubbler containing purified deionized (DI) water.” (Col. 5, lines 22-26). Thus, Emesh is silent about the step of “subjecting the dielectric film to a wet oxidation with steam provided by heating a mixture of *hydrogen and oxygen* gases in a rapid thermal process chamber at a temperature of at least about 450 °C and for a duration which increases the oxygen content of the dielectric film,” as independent amended claim 8 recites. Finally, Chivukula is also silent about “a wet oxidation with a mixture of *hydrogen and oxygen* gases in a rapid thermal process chamber at a temperature of at least about 450 °C . . . wherein *the ratio of hydrogen to oxygen gases in the mixture is in the range of about 0.1 to about 0.8,*” as independent amended claim 8 recites. Chivukula teaches only water vapors in the presence of either oxygen or oxygen/ozone.

Second, no suggestion or motivation to combine the references exists. The crux of Patel is “a method for forming a ferroelectric capacitor using ozone anneals.” (Col. 2, lines 7-8). In fact, the title of Patel’s invention is “Ozone Gas Processing for Ferroelectric Memory Circuits.” (Title). In the “Background” section of the invention, Patel discusses the role of oxygen in the formation of desired ferroelectric properties of PZT (“Annealing in oxygen is necessary to form the correct crystallographic phases” (col. 1, lines 22-

25); “Thus, oxygen is needed to repair these defects” (col. 1, lines 35-36); “Currently, oxygen anneals are done in an O₂ ambient” (col. 1, lines 41-43)). Thus, Patel concludes that the drawbacks of the prior art oxygen anneal processes “can be reduced, or even eliminated” with the use of ozone anneals. (Col. 1, lines 45-47).

In the “Summary” part of the invention, Patel discusses at length all reasons why Patel’s ozone anneals are preferred to the oxygen anneals of the prior art. Patel expressly notes that “ozone is preferred” to oxygen because “[O]zone anneals provide a more complete method of supplying oxygen to the ferroelectric material than oxygen anneals since ozone quickly decays to O₂ and O[•] at temperature above 400°C.” (Col. 2, lines 11-14). Patel further states that “since ozone gas is highly reactive and naturally tries to become stable by giving up an oxygen, ozone is not limited by the same surface adsorption/desorption kinetics as regular O₂.” (Col. 2, lines 17-21). “In other words,” Patel explains, “the ozone molecules decomposes into an oxygen atom and oxygen molecule in a few milliseconds at 500°C or above.” (Col. 2, lines 21-26). “As a result, when a ferroelectric material is exposed to ozone, the ferroelectric material can obtain an oxygen atom much quicker than it can obtain from O₂.” (Col. 2, lines 26-30). Patel concludes that “ozone can provide a higher concentration of reactive oxygen atoms for diffusion into the ferroelectric material which results in a relatively faster diffusion (penetration) of oxygen into the ferroelectric material.” (Col. 2, lines 30-34).

In contrast, both Emesh and Chivukula teach anneal atmospheres which necessarily include oxygen. As noted above, Emesh teaches oxygen (O₂) passing a double bubbler containing purified deionized (DI) water, while Chivukula teaches water vapors in the presence of either oxygen or oxygen/ozone. Accordingly, even if one skilled in the art would have been motivated to combine either Emesh or Chivukula, which teach the use of oxygen, with Patel which fails to teach the use of oxygen alone, the resultant combination would still teach the use of ozone.

In concluding that Patel does not teach against the use of oxygen for wet oxidation processing, the Office Action asserts that “Patel . . . discloses express examples

wherein **oxygen alone** or oxygen-ozone combination anneals are used (column 4, lines 23-35).” (last Office Action at 8). Applicants reaffirm that this assertion is wrong.

Patel teaches “a series of processing steps, including a series of ozone anneals” as part of the method of forming a ferroelectric capacitor. (Col. 2, lines 7-10). In describing the series of ozone anneals, Patel first emphasizes that “ozone is preferred in that it significantly decreases the number of lead (Pb) atoms lost during annealing as compared to using a conventional oxygen anneal in a furnace.” (Col. 4, lines 18-22). Patel then mentions that the anneal “can be conducted using either a single anneal or a combination of anneals.” (Col. 4, lines 23-24). As part of the “combination of anneals,” Patel teaches (1) “an ozone RTA followed by an oxygen RTA”; (2) “an ozone RTA followed by an oxygen furnace anneal”; (3) “an oxygen furnace anneal followed by an ozone RTA”; or (4) “an ozone furnace anneal followed by an oxygen furnace anneal.” (Col. 4, lines 27-33). Thus, Patel does not teach an “oxygen alone” anneal step, as the Office Action mistakenly asserts. Patel teaches either an ozone anneal or, at least, an ozone anneal in combination with an oxygen anneal.

Applicants also note that no suggestion or motivation to combine Patel with Zant exists. As detailed above, the crux of Patel is replacing the oxygen anneals with ozone anneals because “[O]zone anneals provide a more complete method of supplying oxygen to the ferroelectric material than oxygen anneals since ozone quickly decays to O₂ and O⁻ at temperature above 400°C.” (Col. 2, lines 11-14). In contrast, in describing dry oxidation systems as “oxidant sources” for microchip fabrication, Zant specifically emphasizes that a drawback of the dryox system is “the explosive property of hydrogen.” (Zant at 160). For this, Zant teaches that “[P]recautions used to reduce the explosion potential include . . . flowing *excess oxygen* into the tube.” (Zant at 160; emphasis added). In this manner, “*excess oxygen* ensures that every hydrogen molecule (H₂) will combine with an oxygen atom to form the nonexplosive water molecule, H₂O.” (Zant at 160; emphasis added). Accordingly, one skilled in the art would not have been motivated to combine Zant, which specifically teaches the use of oxygen to overcome the explosion potential of a dryox

system, with Patel, which teaches against the use of oxygen. For at least these reasons, the Office Action failed to establish a *prima facie* case of obviousness and withdrawal of the rejection of claims 8, 2-5 and 10-12 is respectfully requested.


New claims 41-44 have been added to round out the scope of protection afforded by the invention. The cited references, whether considered alone or in combination, fail to teach or suggest the subject matter of these claims, including a “method of fabricating a semiconductor device” by *inter alia* “depositing a silicon nitride film over an underlying layer” and “subjecting the silicon nitride film to a wet oxidation with a mixture of hydrogen and oxygen gases in a rapid thermal process chamber at a temperature of at least about 450 °C and for a duration which increases the oxygen content of the silicon nitride film,” as newly added claim 41 recites. The cited references also fail to teach or suggest a “method of fabricating a semiconductor device” by *inter alia* subjecting a dielectric film to a wet oxidation “with steam provided by heating a mixture of hydrogen and oxygen gases in a rapid thermal process chamber . . . the steam being provided by a catalytic system” (claim 42) or “by a pyrogenic system” (claim 43) or “by a bubbled water vapor system” (claim 44).

A marked-up version of the changes made to the specification and claims by the current amendment is attached. The attached page is captioned “Version with markings to show changes made.”

In view of the above, each of the presently pending claims in this application is believed to be in immediate condition for allowance. Accordingly, the Examiner is respectfully requested to withdraw the outstanding rejection of the claims and to pass this application to issue.

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Respectfully submitted,

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VERSION WITH MARKINGS TO SHOW CHANGES MADE

8. (four times amended) A method of fabricating a semiconductor device comprising:

depositing an oxygen-deficient dielectric film having a dielectric constant of at least about 25 over an underlying layer;

subjecting the dielectric film to a wet oxidation with steam provided by heating [from] a mixture of hydrogen and oxygen gases in a rapid thermal process chamber at a temperature of at least about 450 °C and for a duration which increases the oxygen content of the dielectric film, wherein the ratio of hydrogen to oxygen gases in the mixture is in the range of about 0.1 to about 0.8; and

subjecting the dielectric film to a heat treatment in an ambient comprising a stabilizing gas selected from the group consisting of N₂, O₂, O₃, NO, and N₂O.